Chapter II

Review of Literature
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The purpose of this study was to attempt to examine any inter segmental similarities that exist between the under-arm, side-arm and over-head throws used in the sport of cricket. The purpose of the review of literature was to examine any previous research that is related to throwing mechanism.

The throwing motion is identical complex. This has led to many different methodologies being used to analyze, the biomechanics of the Biomechanical analysis of throwing techniques. Different temporal, kinematic, and kinetic parameters are selected based upon their necessity for each individual study. Also forms of methods are being used to collect the motion data including varying numbers and locations for 2D and 3D motion analysis research.

2.1 Previous Studies Findings

Hussain & Bari, (2011) have studied on “Biomechanical Analysis of Cricket Ball Throwing Techniques”. This research article looks at the kinematic characteristics of different throwing techniques (under-arm,
side-arm and over-head) with particular stress on the techniques of throwing in cricket. The technique is subdivided into: (1) Wind up phase, (2) late cocking Phase and (3) arm acceleration phases. The study was used to form the samples as, sixty (60) elite cricket players. The mean age of the cricket players were (21.82±3.08) years, height – (62.38±7.22cm), weight (168.07±6.68kg). Each throwing techniques successful attempt for throwing distances 30m with 45° approach angle at 45°, 90° and 180° target angle from the stump were recorded using Canon Legaria SF-10, 8.1 Mp cameras in a field setting with (1/2000 shutter speed and at 60 fps). The cameras were set-up on a rigid tripod and secured to the floor in the location. First camera was located to obtain maximum accuracy and second camera located to view the throwing performances, at given specified distance in the reconstruction of the two dimensional coordinate. The location of camera were chosen so that the optical axes of camera intersected perpendicularly to the designated plane .The accuracy of throwing performances were considered in identify the footage for addition and were subjected to analysis. Result revealed that the significant mean difference were found among different throwing kinematics as well as ball velocity and accuracy and the ball speed had to be high to carry the full distance of the throw in the shortest time.
Hussain & Bari, (2011) have studied on “Mechanical Analysis of Overhead Throwing in Cricket”. This paper considers the kinematic characteristics of over arm throwing with particular emphasis on the techniques of throwing in cricket. The technique is subdivided into: (1) Wind up phase, (2) late cocking Phase (3) arm acceleration and (4) instant of ball release. The study was used to form the samples as, 10 elite cricket players. The ages of the players were (mean ± 23.50). The physical characteristics of height (Mean: 169.4-172.4cm)), weight (57.8-61.3). Each over head maximal and sub maximal successful attempt for each throwing distances 20m and 10m with 180°,112° and 45° approach angle at 90° target angle from the stump were recorded using Sony DV cameras in a field setting with (1/2000 shutter speed and at 60fps). The cameras were set-up on a rigid tripod and secured to the floor in the location. First camera was located to obtain maximum accuracy and second camera located to view the throwing performances, at given specified distance in the reconstruction of the two dimensional coordinate. The location of camera were chosen so that the optical axes of camera intersected perpendicularly to the designated plane .The accuracy of throwing performances were considered in identify the footage for addition and were subjected to analysis. Result revealed that the ball
speed had to be high to carry the full distance of the throw in the shortest time.

Wagner, Pfusterschmied & Serge, (2011) have studied on “Performance and kinematics of various throwing techniques in team hand ball” In team-handball competition, the players utilize various throwing techniques that differ in the lower body movements (with and without run-up or jump). These different lower body movements influence changes in the upper body movements and thus also affect the performance. A comprehensive analysis of 3D-kinematics of team-handball throws that may explain these differences in performance is lacking. Consequently, the purpose of this study was (1) to compare performance (ball velocity and throwing accuracy) between the jump throw, standing throw with and without run-up, and the pivot throw; (2) to calculate the influence of kinematic parameters to ball velocity; and (3) to determine if these four throwing techniques differ significantly in kinematics. Three-dimensional kinematic data (angles, angular velocities and their timing, ball velocity and velocity of the center of mass) of 14 elite team-handball players were measured using an 8 camera Vicon MX13 motion capture system (Vicon, Oxford, UK), at 250 Hz. Significant difference was found between the four throwing techniques for ball velocity (p < 0.001), maximal velocity of the center of mass in
goal-directed movement (p < 0.001), and 15 additional kinematic variables (p < 0.003). Ball velocity was significant impacted by the run-up and the pelvis and trunk movements. Depending on floor contact (standing vs. jump throws), elite players in the study used two different strategies (lead leg braces the body vs. opposed leg movements during flight) to accelerate the pelvis and trunk to yield differences in ball velocity. However, these players were able to utilize the throwing arm similarly in all four throwing techniques.

Hussain, Bari, Khan, Mohammad, & Ahmad, (2011) have studied on “Accuracy-Velocity Relationship and Physical Characteristics in Cricket Ball Throwing”. This study was designed to assess the relationship between segmental lengths, accuracy, and velocity of cricket ball throwing ability of cricket players. The ex-post-facto design was used to form the samples as, 10 junior and 10 senior cricket players. The age of the junior players were between 14-18 years, while that of the senior players were above 18 years of age. The physical characteristics of height (Mean: 169.4-172.4cm)), weight (57.8-61.3), segmental length (25.54-38.48). Ten attempt for each throwing techniques (under-arm; side-arm and over-head throws) were recorded using Sony DV cameras in a field setting with (1/2000 shutter speed and at 30-60fps). The cameras were set-up on a rigid tripod and secured to the floor in the location. First
camera was located to obtain maximum accuracy and second camera located to view the throwing performances, at given specified distance in the reconstruction of the two dimensional co-ordinate. The location of camera were chosen so that the optical axes of camera intersected perpendicularly to the designated plane. The accuracy of throwing performances were considered in identify the footage for addition and were subjected to analysis. Only one successful and one unsuccessful performance were considered from ten attempts. The statistical analysis revealed no insignificant differences in the throwing accuracy and velocity of the ball and no significant relationship between the upper and lower body segments of the junior and senior cricket players. These indicate that there is no particular body segment that contributes to throwing ability independently. Therefore there is a need for the cricket players to improve on their throwing skills through specialized practice for different throws, through a well harnessed daily programme. Also, coaches need to study each players throwing mechanics in order to correct, where necessary, for better throwing performances.

Cheng-Hsin, Po-Yi, Chia-Wei, Hsien, & Yung-Shen, (2010) have studied on “Throwing Kinematics in Youth Pitchers and Field Players”. Ten pitchers (age: 11.1±0.7 years; height: 149.5±10.2 cm; weight: 43.3±11.6kg) and 10 field players (age: 11.2±0.8 years; height:
146.6±6.3cm; weight: 38.5±8.8kg) with overhead throwing pattern were recruited for this study. Throwing kinematics was assessed using a 3D electromagnetic motion tracking system. A foot switch was used to determine the instant of foot strike. The instant of ball release was defined as the instant when wrist acceleration phase was becoming deceleration phase. Three fast balls that hit a target placed 14.63m away were recorded for data analysis. Independent t-tests were performed for comparing the differences in throwing kinematics, body, height, and weight between the two groups. Significant level was set at p<0.05. Only maximum upper torso rotational velocity during acceleration phase of throwing was found to be greater in pitchers when compared to the field players. (1015.4+74.4 vs. 906.0+104.6°/s; p= 0.015). No significant differences in shoulder abduction angle at foot strike, maximum elbow flexion angle, shoulder abduction angle at ball release, trunk side-bending at ball release, and maximum velocity of shoulder horizontal adduction, shoulder internal rotation, upper and lower torso rotation, and elbow extension were found between the two groups. There were also no significant differences in body weight and height between the two groups. Throwing kinematic variables observed in this study were similar between youth pitchers and field players except that pitchers had greater maximum upper torso rotational velocity that was not one of the
kinematic variables significantly affecting elbow valgus stress based on the previous studies.

Layera, (2010) has studied on “A comparison of the differences in trunk and lower body kinematics and their effects on ball velocity in an over-arm throw between a skilled and less skilled performer.” The purpose of this study is to support literature representing the importance of lower body technique in the over-arm throw through the comparison of a skilled and non-skilled performer. Ball velocity, stride length (in meters and as a percentage of performer’s body height), trunk forward tilt and the change in knee angle from front foot contact to ball release were compared between performers to check for versions in technique. The two performers performed 6 successful throws at maximum velocity at a target area on a wall – all performances were filmed and digitized and data was entered into SPSS where independent T-tests were run to check for substantial differences (p < .05) in the parameters between the performers. Results showed significant differences in stride length (m), knee flexion and ball velocity, while stride length (%BH) and trunk flexion were non-significant. Determinations suggest that lower body technique in the throw is of high importance and more time should be devoted to it during the coaching of the throw.
Aguinaldo & Chambers, (2009) have studied on Sixty-nine adult baseball players pitched off an indoor mound during 3-dimensional motion analysis to measure whole body kinematics and kinetics at 240 Hz. Thirteen biomechanical parameters were calculated and extracted for regression analysis to investigate their connections with elbow valgus load. A 2-way analysis of variance compared valgus torques between throwers with 2 onsets of trunk rotation (before and after front-foot contact) and 2 arm slot positions (overhand and sidearm). Six biomechanical variables had substantial correlations (P < .02) with elbow valgus torque—with level best shoulder external rotation, elbow flexion at peak valgus torque, and elbow valgus loading rate being 68% of its variance. Diluted elbow valgus torques’s were linked with increased elbow flexion (P < .01). Players who started trunk rotation before front-foot contact had importantly higher elbow valgus torques than did those who rotated later on (P = .02). Fourteen pitchers displayed a sidearm delivery and had significantly higher elbow valgus torques than did those with an overhand arm slot position. Valgus torque at the elbow during baseball throwing is associated with 6 biomechanical variables of successive body motion. A specify of late trunk rotation, reduced shoulder external rotation, and changed elbow flexion appeared to be
most nearly related to valgus torque. Sidearm pitchers came out to be more susceptible than overhand pitchers to reduced elbow valgus torque.

Fleisig, (2009) has studied on “Kinematic and kinetic comparison of baseball pitching among various levels of development”. In this study, 23 youth, 33 high school, 115 college, and 60 professional baseball pitchers were analyzed. Sixteen kinematic (11 position and five velocity), eight kinetic, and six temporal parameters were estimated and compared among the four levels of contest. Only one of the 11 kinematic position parameters showed significant differences among the four levels, while all five velocity parameters established significant differences. All eight kinetic parameters changed significantly with competition level. None of the six temporal parameters showed significant conflicts. Since 16 of the 17 position and temporal parameters showed no significant differences, this study supports the philosophy that a child should be taught ‘proper’ pitching mechanics for use throughout a career. Kinetic differences observed propose greater injury risk at higher competition levels. Since adult pitchers did not demonstrate different position or temporal patterns than younger pitchers, increases in joint forces and torques were most likely due to increased strength and muscle mass in the higher level athlete. The greater shoulder and elbow angular velocities produced by high-level pitchers were most likely due to the greater torques they
generated during the arm cocking and acceleration phases. The combination of more arm angular velocity and a longer arm resulted in greater linear ball velocity for the higher level pitcher. Thus, it appears that the natural progression for successful pitching is to learn proper mechanics as early as possible, and build strength as the body matures.

Hong, (2009) has study on “A three-dimensional, six-segment chain analysis of forceful over-arm throwing”. A three-dimensional, six-segment model was applied to the pitching motion of three professional pitchers to analyze the kinematics and kinetics of the hips, upper trunk, humerus and forearm plus hand of both the upper limbs. Subjects were filmed at 250 frames per second. An inverse dynamics approach and angular momentum principle with respect to the proximal endpoint of a rigid segment were employed in the analysis. Results showed considerable similarities between subjects in the kinetic control of trunk rotation about the spine's longitudinal axis, but variability in the control of trunk lean both to the side and forward. The kinetics of the throwing shoulder and elbow joint were comparable between subjects, but the contribution of the non-throwing upper limb was minimal and variable. The upper trunk rotators played a key role in accelerating the ball to an early, low velocity near stride foot contact. After a brief pause they resumed acting strongly in a positive direction, though not enough to
prevent trunk angular velocity slowing, as the musculature of the arm applied a load at the throwing shoulder. The interaction moment from the proximal segments assisted the forearm extensor in slowing flexion and producing rapid elbow extension near ball release. The temporal onset of muscular torques was not in a strictly successive proximal-to-distal sequence.

Sparrow, (2009) has studied on “Visual perception of action categories and the bowl-throw decision in cricket”. notice that Cricket umpires, cricket bowlers, and physical education students (who were knowledgeable about the rules of cricket), were shown 72 videotaped point-light displays of cricket deliveries with varying extents of elbow flexion such that they ranged from highly “bowl-like” to highly “throw-like”. The observers made a bowl-throw decision about each display, and the umpires and bowlers reported their confidence on a 5-point scale. The percentage of displays reported as a “bowl” was 59, 40, and 44 for the umpires, bowlers, and students respectively. Umpires made significantly more bowl decisions than both the bowlers and students, but there was no difference between the latter groups. Umpires were significantly more confident than the bowlers in both their bowl and throw decisions. Thus in an experimental setting, with no apparent costs or benefits associated with their decision-makin, umpires “called” a bowler significantly less
frequently for throwing than other knowledgeable observers. The procedures devised for this experiment demonstrate that psychophysical methods can be applied to the problem of discrete action-category nominations in sport (e.g., bowl or throw, walk or run).

Werner, Suri, Guido, Meister, & Jones, (2008) have studied on “Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers”. Although ball speed is considered a measure of success in baseball pitching, little is known about the relationship between ball velocity and pitching mechanics. Investigation of this relationship has been limited, and the studies carried out have varied in methodology. Three-dimensional, high-speed (240 Hz) video data were collected on fastballs from 54 collegiate baseball pitchers. Kinematic parameters related to pitching mechanics and resultant kinetics on the throwing shoulder and elbow were calculated. Multiple linear regression analysis was used to relate ball velocity and pitching mechanics. Ball velocity averaged 35 m/sec (79 mph) for the 54 college pitchers. Nearly 70% of the variability in ball speed can be explained by a combination of 10 parameters related to pitching mechanics. Body mass and 9 temporal and kinematic parameters related to pitching mechanics combine to account for 68% of the variance in ball velocity for a collegiate population of athletes. These variables can be manipulated via
mechanical changes and sport-specific training to affect ball velocity. The results of the study can be used to increase ball velocity while at the same time minimizing stresses on the throwing arm elbow and shoulder. Improved training programs can begin to be developed based on these data.

Dun, Loftice, Fleisig, Kingsley, & Andrews, (2008) have studied on “A Biomechanical Comparison of Youth Baseball Pitches”. Twenty-nine youth baseball pitchers (age, 12.5 ± 1.7 years) pitched 5 fastballs, 5 curveballs, and 5 change-ups with maximum effort in an indoor laboratory setting. Data were collected with a 3-dimensional motion analysis system. Kinetic, kinematic, and temporal parameters were compared among the 3 pitches. They cited in this study for elbow varus torque, shoulder internal rotation torque, elbow proximal force, and shoulder proximal force, the fastball produced the greatest values, followed by the curveball and then the change-up. The fastball also produced the greatest elbow flexion torque. Shoulder horizontal adduction torque and shoulder adduction torque were the least for the change-up. Several differences in body segment position, velocity, and timing were also found in generally coincide on in general, elbow and shoulder loads were the greatest in the fastball and least in the change-up.
Kinematic and temporal differences were also found among the 3 pitch types.

Hirashimaab, Yamanec, Nakamurac, & Ohtskid, (2008) have studied on “Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis”. This study investigated how baseball players generate large angular velocity at each joint by coordinating the joint torque and velocity-dependent torque during over-arm throwing. Using a four-segment model (i.e., trunk, upper arm, forearm, and hand) that has 13 degrees of freedom, they are conducted the induced acceleration analysis to determine the accelerations induced by these torques by multiplying the inverse of the system inertia matrix to the torque vectors. They found that the proximal joint motions (i.e., trunk forward motion, trunk leftward rotation, and shoulder internal rotation) were mainly accelerated by the joint torques at their own joints, whereas the distal joint motions (i.e., elbow extension and wrist flexion) were mainly accelerated by the velocity-dependent torques. This study further examined which segment motion is the source of the velocity-dependent torque acting on the elbow and wrist accelerations. The results showed that the angular velocities of the trunk and upper arm produced the velocity-dependent torque for initial elbow extension acceleration. As a result, the elbow joint angular velocity increased, and concurrently, the
forearm angular velocity relative to the ground also increased. The forearm angular velocity subsequently accelerated the elbow extension and wrist flexion. It also accelerated the shoulder internal rotation during the short period around the ball-release time. These results indicate that baseball players accelerate the distal elbow and wrist joint rotations by utilizing the velocity-dependent torque that is originally produced by the proximal trunk and shoulder joint torques in the early phase.

Michael, Reinold., Kevin, Wilk, Macrina, Sheheane, Dun, Fleisig, Crenshaw, & Andrews, (2008) have studied on “Changes in Shoulder and Elbow Passive Range of Motion After Pitching in Professional Baseball Players”. Sixty-seven asymptomatic male professional baseball pitchers participated in the study. Passive range of motion measurements were recorded using a customized bubble goniometer for shoulder external rotation, shoulder internal rotation, total shoulder rotational motion, elbow flexion, and elbow extension on the dominant and non dominant arms. Testing was performed on the first day of spring training. Measurements were taken before, immediately after and 24 hours after pitching. A significant decrease in shoulder internal rotation (−9.5°), total motion (−10.7°), and elbow extension (−3.2°) occurred immediately after baseball pitching in the dominant shoulder (P<.001). These changes continued to exist 24 hours after pitching. No differences were noted on
the non dominant side. Passive range of motion is significantly decreased immediately after baseball pitching. This decrease in range of motion continues to be present 24 hours after throwing. High levels of eccentric muscle activity have previously been observed in the shoulder external rotators and elbow flexors during pitching. These eccentric muscle contractions may contribute to acute musculo-tendinous adaptations and altered range of motion. The results of this study may suggest a newly defined mechanism to range of motion adaptations in the overhead throwing athlete resulting from acute musculoskeletal adaptations, in addition to potential osseous and capsular adaptations.

Sasakawa & sakurai, (2008) have studied on “Biomechanical analysis of the sidearm throwing motion for distance of a flying disc: A comparison of skilled and unskilled Ultimate players”. Joint angles of the throwing limb were examined from the acceleration phase up until release for the sidearm throwing motion when using a flying disc. 17 individuals (ten skilled, seven unskilled) threw a disc as far as possible ten times. Throwing motions were recorded using three-dimensional high-speed videography. The initial condition of disc release and joint angle kinematics of the upper limb during the throwing motion were obtained. Mean (±standard deviation) throwing distance and disc spin rate were significantly greater for skilled throwers (51.4 ± 6.6 m, 12.9 ± 1.3 rps)
than for unskilled throwers (29.5 $\pm$ 7.6 m, 9.4 $\pm$ 1.3 rps), although there was no significant difference in initial velocity of the disc between the two groups (skilled: 21.7 $\pm$ 1.7 m/s; unskilled: 20.7 $\pm$ 2.5 m/s). A marked difference in motion of supination/pronation of the forearm before disc release was identified, with the forearm supinated in the final acceleration phase leading up to disc release for the unskilled participants, while the forearm was pronated in the same phase for the skilled participants. These differences in joint kinematics could be related to differences in disc spin rate, and thus led to the substantial differences in throwing distance.

Davis, Hackett, Thomas, Keirns, Mike, Sabick, Michelle, & Torry, (2008) have studied on “A Biomechanical Analysis of Youth Pitching Mechanics” Sixteen healthy right hand-dominant baseball pitchers participated in this study. After digitization of 21 bony landmarks, kinematic calculations were conducted using the 3-dimensional coordinates from each video frame. Data were time normalized, forcing major temporal components of the movement to occur at specific intervals. Segment-based reference frames were established, and resultant joint kinetics were projected onto each reference frame. Kinetic data were normalized and calculated along or about the anterior/posterior, medial/lateral, and proximal/distal axes. Maximum trunk rotation and external shoulder rotation were observed during arm cocking. Each of the
remaining kinematic parameters peaked after ball release. All maximum values for joint kinetics were measured during arm cocking with the exception of compressive forces experienced at the shoulder and elbow, which peaked after the instant of ball release. Data produced in this study indicate that youth pitchers initiate trunk rotation early in the movement, which can lead to shoulder hyper angulation. Opposing torques at each end of the humerus also produce a large net torque about the longitudinal axis of the humerus during late arm cocking and may increase humeral retrotorsion in youth pitchers. Underdeveloped musculature in the rotator cuff may lead to difficulty controlling throwing-arm deceleration, causing an increase in horizontal adduction across the torso.

Dun, Fleisig, Loftice, Kingsley, & Andrews, (2007) have studied on the relationship between age and baseball pitching kinematics in professional baseball pitchers. They cited that Joint range of motion and physical capacities have been shown to change with age in both throwing athletes and non-athletes. The age of professional baseball pitchers could span from late teens to mid-40s. However, the effects of age on the pitching kinematics among professional baseball pitchers are still unknown. In this study, 67 healthy professional baseball pitchers were tested using a 3D motion analysis system. Their mean age was 23.7±3.3 years (range 18.8–34.4). The 12 pitchers more than one standard deviation older than the
mean (i.e., older than 27.0 years) were categorized into the older group, and the 10 pitchers more than one standard deviation younger than the mean (i.e., younger than 20.4 years) were defined as the younger group. In all, 18 kinematic variables (14 position and 4 velocity) were calculated, and Student's t-tests were used to compare the variables between the two groups. Six position variables were found to be significantly different between the two groups. At the instant of lead foot contact, the older group had a shorter stride, a more closed pelvis orientation, and a more closed upper trunk orientation. The older group also produced less shoulder external rotation during the arm cocking phase, more lead knee flexion at ball release, and less forward trunk tilt at ball release. Ball velocity and body segment velocity variables showed no significant differences between the two groups. Thus, differences in specific pitching kinematic variables among professional baseball pitchers of different age groups were not associated with significant differences in ball velocities between groups. The current results suggest that both biological changes and technique adaptations occur during the career of a professional baseball pitcher.

Escamilla, Barrentine, Fleisig Zheng, Takada, Kingsley, & Andrews, (2007) have studied on “Pitching Biomechanics as a Pitcher Approaches Muscular Fatigue During a Simulated Baseball Game”. Ten collegiate
baseball pitchers threw 15 pitches per inning for 7 to 9 innings off an indoor throwing mound during a simulated baseball game. A pitching session ended when each pitcher felt he could no longer continue owing to a subjective perception of muscular fatigue. A 6-camera 3D automatic digitizing system collected 200-Hz video data. Twenty kinematic and 11 kinetic variables were calculated throughout 4 phases of the pitch. A repeated-measure analysis of variance ($P < .01$) was used to compare biomechanical variables between innings. Compared with the initial 2 innings, as a pitcher approached muscular fatigue during the final 2 innings he was able to pitch, there was a significant decrease in ball velocity, and the trunk was significantly closer to a vertical position. There were no other significant differences in kinematics or kinetics variables. The relatively few differences observed imply that pitching biomechanics remained remarkably similar between collegiate starting pitchers who threw between 105 and 135 pitches for 7 to 9 innings and approached muscular fatigue. This study did not support the idea that there is an increase in shoulder and elbow forces and torques as muscular fatigue is approached. It is possible that if a pitcher remained in a fatigued state for a longer period of time, additional changes in pitching mechanics may occur and the risk of injury may increase.
Whiteley, (2007) has studied on “Baseball throwing mechanics as they relate to pathology and performance”. It is a commonly held perception amongst biomechanics’, sports medicine practitioners, baseball coaches and players, that an individual baseball player’s style of throwing or pitching influences their performance and susceptibleness to injury. With the results of a series of focus groups with baseball managers and pitching coaches in mind, the available scientific literature was reviewed regarding the contribution of individual aspects of pitching and throwing mechanics to potential for injury and performance. After a discussion of the limitations of kinematic and kinetic analyses, the individual aspects of pitching mechanics are discussed under arbitrary headings: Foot position at stride foot contact; Elbow flexion; Arm rotation; Arm horizontal abduction; Arm abduction; Lead knee position; Pelvic orientation; Deceleration-phase related issues; Curveballs; and Teaching throwing mechanics. In general, popular opinion of baseball coaching staff was found to be largely in concordance with the scientific investigations of biomechanics’ with several notable exceptions. Some difficulties are identified with the practical implementation of analyzing throwing mechanics in the field by pitching coaches, and with some unquantified aspects of scientific analysis.
Sachlikidis & Salter, (2007) have studied on “A biomechanical comparison of dominant and non-dominant arm throws for speed and accuracy”. Training a non-dominant limb may increase a competitor’s ability to perform with either side of his or her body and confer an advantage over contenders that use one side of the body exclusively. The aim of this study was to determine the kinematic differences between dominant and non-dominant arm-throwing techniques for speed and accuracy in Under-17 and Under-19 high-performance cricketers. Seven participants performed ten throws for each arm (dominant/non-dominant) and condition (speed/accuracy) at a target positioned 10 m in front of them. Three-dimensional kinematic variables were measured using a Vicon motion analysis system. Digital footage was used to calculate stride data, ball speed, and record target accuracy. Data were analysed using repeated-measures analysis of variance and chi-squared tests. The non-dominant arm throws had significantly lower maximum lead knee lift, did not extend the lead knee in the arm acceleration phase, had significantly less elbow flexion before extension, had significantly less shoulder external rotation at the start of the arm acceleration phase, did not have a delay between the initiation of pelvic and upper torso internal rotation, and displayed a less than optimal coordination pattern. A speed–accuracy trade-off existed for the dominant arm throws. No trade-off was
identified for the non-dominant arm throws. Through an enhanced understanding of how throwing technique varies between dominant and non-dominant arms, an opportunity exists for a performance-enhancing programme to be implemented so that ambidexterity of the throwing skill can be improved.

Linthorn & Everett, (2006) have investigated “The release angle that maximizes the distance attained in a long soccer throw-in”. One male soccer player performed maximum-effort throws using release angles of between 10 and 60 degrees, and the throws were analysed using 2-D video. The player's optimum release angle was calculated by substituting mathematical expressions for the measured relations between release speed, release height, and release angle into the equations for the flight of a spherical projectile. We found that the musculoskeletal structure of the player's body had a strong influence on the optimum release angle. When using low release angles the player released the ball with a greater release speed, and because the range of a projectile is strongly dependent on the release speed, this bias toward low release angles reduced the optimum release angle to about 30 degrees. Calculations showed that the distance of a throw may be increased by a few metres by launching the ball with a fast backspin, but the ball must be launched at a slightly lower release angle.
Wright, Steger-May, Wasserlauf, O’Neal, Weinberg, and Paletta, (2006) have studied on “Elbow Range of Motion in Professional Baseball Pitchers”. Thirty-three professional pitchers were evaluated for elbow range of motion during spring training preseason physical examination. Dominant and non dominant elbow range of motion including flexion, extension, supination, and pronation were measured with a goniometer. Ranges of motion measures from the dominant and non dominant sides were compared. Baseball records were reviewed for arm dominance, age, years of professional pitching, professional innings pitched, and history of elbow surgery. These factors were evaluated for their possible association with range of motion for each side and the difference between sides. Statistically significant differences between dominant and non dominant sides were noted for elbow extension (dominant decreased $7.9^\circ \pm 7.4^\circ$, $P< .0001$), flexion (dominant decreased $5.5^\circ \pm 7.8^\circ$, $P = .0003$), and total flexion-extension arc (dominant decreased $13.3^\circ \pm 13.7^\circ$, $P< .0001$). No significant difference between sides was found for the supination or pronation measures. No correlation was noted for age, pitching history, surgery, or arm dominance and the motion differences. Professional pitchers demonstrate elbow flexion and extension differences between dominant and non dominant elbows. No correlation
was found between motion differences and age, pitching history, surgery, or arm dominance.

Stodden, David, Langendorfer, Stephen, Fleisig, Andrews, & James, (2006) have studied on “kinematic constraints associated with the acquisition of over-arm throwing”. The purposes of this study were to: (a) examine differences within specific kinematic variables and ball velocity associated with developmental component levels of step and trunk action and (b) if the differences in kinematic variables were significantly associated with the differences in component levels, determine potential kinematic constraints associated with skilled throwing acquisition. Results indicated stride length (69.3%) and time from stride foot contact to ball release (39.7%) provided substantial contributions to ball velocity (p< .001). All trunk kinematic measures increased significantly with increasing component levels (p< .001). Results suggest that trunk linear and rotational velocities, degree of trunk tilt, time from stride foot contact to ball release, and ball velocity represented potential control parameters and, therefore, constraints on overarm throwing acquisition.

Jegede, Watts, Stitt, & Hore, (2005) have studied on “Timing of ball release in over-arm throws affects ball speed in unskilled but not skilled individuals”. They cited the hypothesis that variability in the timing of
ball release in overarm throws affects ball speed. Nine unskilled and six skilled throwers made 30 throws fast and accurately from a sitting and standing position. Angular positions of finger and arm segments were recorded with search-coils at 1000 Hz; ball speed was measured with a radar gun. The time of ball release from the fingertips was measured with respect to seven arm kinematic reference points. Mean timing windows for ball release were 28 ms for unskilled throwers and 37 ms for skilled throwers. Mixed-model analyses of variance showed that there was a statistically significant relationship between ball speed and the timing of ball release in unskilled throwers, but not in skilled throwers. This was presumably due to the difference in variability of the timing of ball release between the two groups. In contrast, skilled throwers showed a relationship between ball speed and peak forearm angular velocity (one measure of arm speed). We conclude that although variability in the timing of ball release can affect ball speed, this is only a major factor in unskilled throwers. When skilled throwers throw fast, variability in ball speed is due to variability in arm speed.

Sabick, Young-Kyu, Torry, Keirns, & Hawkins, (2005) have studied on “Biomechanics of the Shoulder in Youth Baseball Pitchers”. A total of 14 elite youth baseball pitchers (mean age, 12.1 ± 0.4 years) were filmed from the front and dominant side while throwing fastballs in a simulated
The net force and torque acting on the humerus throughout the throwing motion were calculated using standard biomechanical techniques. The external rotation torque about the long axis of the humerus reached a peak value of $17.7 \pm 3.5 \text{ N-m}(2.7\% \pm 0.3\% \text{ body weight x height})$ just before maximum shoulder external rotation. A shoulder distraction force of $214.7 \pm 47.2 \text{ N}(49.8\% \pm 8.3\% \text{ body weight})$ occurred at, or just after, ball release. The stresses generated by the external rotation torque are much greater than those caused by distraction forces generated during the pitching motion of youth baseball pitchers.

Debicki, Gribble, Watts, & Hore, (2004) have studied “kinematics of wrist joint flexion in over-arm throws made by skilled subjects”. Previous studies of multi joint arm movements have shown that the CNS holds arm kinematics constant in different situations by predictively compensating for the effects of interaction torques. We determined whether this was also the case for wrist joint flexion in natural over-arm throws performed by skilled subjects in 3D, a situation where large passive torques can occur at the wrist. Specifically, investigated whether wrist flexion amplitudes are held constant in throws of different speeds. Joint rotations were recorded at 1,000 Hz with the search-coil technique. It is concluded that wrist flexion in over-arm throws of different speeds is produced by central signals which precisely control net joint torque by both exploiting
and damping passive torques during different parts of the throw to keep wrist joint angular position parameters constant. As such the results show that control strategies for natural 3D throwing are different from those for constrained 2D throwing.

James, Carre, & Haake, (2004) has studied on “The playing performance of county cricket pitches”. The surface on to which a bowler projects a ball in the game of cricket is made up of hard packed soil with sparse grass cover. This natural turf pitch is of fundamental importance to the play of the game and the quality of the surface is a prime concern of players, officials, commentators and spectators alike. A programme of research has been undertaken to identify the factors that lead to the construction of high quality cricket pitches. This work employed the technology of high-speed video analysis to monitor the performance of first class cricket pitches during county matches. A system for measuring the impact of a cricket ball on a pitch was developed, and over 3000 ball impacts analysed. This analysis enabled pitches to be characterized in terms of pace, bounce and consistency. Soil properties for the monitored pitches were identified and correlations were drawn between pitch performance and soil composition.

Naughton, Timmann, Watts, & Hore, (2004) have studied on “Over-arm throwing speed in cerebellar subjects: effect of timing of ball release”.

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Cerebellar subjects cannot throw fast and show variability in ball speed from throw to throw. One possible reason is that they release the ball at times when arm speed is not at its maximal value. Therefore, we investigated the hypothesis that the slow and variable speeds of throws made by cerebellar subjects are caused by their known large variability in the timing of ball release. Eight cerebellar subjects and matched controls were instructed to make over-arm throws fast and accurately. Angular positions of arm segments were recorded with search coils at 1,000 Hz. Timing of ball release was measured with respect to the time of occurrence of seven arm kinematic reference points. All cerebellar subjects showed strong relations between ball speed and the timing of ball release, with faster ball speeds associated with late ball release. In agreement, faster ball speeds were also associated with longer hand paths to ball release, and with balls which went low on the target. However, when timing of ball release was optimal for achieving maximal ball speed in the cerebellar subjects, their fastest ball speeds were on average only 67% those of controls. Similarly, peak forearm angular velocity (one measure of arm speed) in the cerebellar group was 58% that of the control group. It is concluded that the large variability in timing ball release in cerebellar subjects contributes to their variability in ball speed, but is only a minor factor in their inability to throw fast. The major reason why
cerebellar subjects do not throw fast is that they do not generate fast arm speeds.

Cross, (2004) has studied on “Physics of over-arm throwing”. Measurements are presented of the speed at which objects of different mass can be projected by an over arm throw. Dismount objects can be thrown faster than heavy objects, although the difference in speed is not as large as one might expect. For a factor of 60 increases in the thrown mass, there was a decrease of only 2.4 in the throw speed. The relatively small change in throw speed is due to the fact that the force that can be applied to a thrown object increases with object mass. Estimates of the muscle forces involved indicate that the increase in force with mass is primarily an inertial rather than a physiological effect. The total kinetic energy of the mass, hand, and the fore arm was found to be almost independent of the object mass, and the throw speed is almost independent of the mass of the upper arm.

Tillaar & Ettema, (2004) have studied on a force-velocity relationship and coordination patterns in over arm throwing. Seven experienced handball players were filmed at 240 frames per second. Velocity of joints of the upper extremity and ball together with the force on the ball were derived from the data. A statistically significant negative relationship
between force and maximal ball velocity, as well as between ball weight and maximal ball velocity was observed. Also, with increase of ball weight the total throwing movement time increased. No significant change in relative timing of the different joints was demonstrated, suggesting that the subjects did not change their "global" coordination pattern (kinematics) within the tested range of ball weights. A simple model revealed that 67% of ball velocity at ball release was explained by the summation of effects from the velocity of elbow extension and internal rotation of the shoulder. With regard to the upper extremity the internal rotation of the shoulder and elbow extension are two important contributors to the total ball velocity at release.

Watts, Pessotto, Hore, and Jon, (2004) have studied on “A simple rule for controlling over-arm throws to different targets”. Watts et al., investigated the central programming of over-arm throws by determining whether throws to spatially separate targets in the vertical direction (sagittal plane) are produced by changes in hand (i.e., finger) path direction or by changes in the timing of ball release. Six skilled throwers made 30 throws at the same speed with a baseball, from a sitting position with the chest fixed, at targets at different heights and distances. Arm segment angular positions in 3D were recorded with the search-coil technique. Videotaping revealed that ball direction was not, as commonly
assumed, the tangent to the finger path at ball release. Rather ball
direction was the tangent to the finger path at a point about half way
between initial uncoupling of the ball from the hand and final ball release.
When viewed from the side, finger paths were tilted upwards for the high
and the far targets and downwards for the low and near targets. This was
associated with changes in angular orientation of the upper arm in space.
Throwing at spatially different targets was not associated with changes in
the timing of ball release. We propose that there is a simple rule by which
throws to targets in different directions and at different distances are
controlled: throws of the same speed are produced by different finger
path directions, but the same timing of ball release. Such a mechanism
would simplify the neural control of throwing to different targets were
significantly correlated to both the classification and measured distance
(p<0.05). The results indicate that shoulder girdle movement during the
delivery is an important determinant of classification and measured
distance.

Dan, (2002) has studied on “Change in throwing pattern: Critical values
for control parameter of velocity”. The purpose of this study was to
determine the critical values at which throwing patterns change when
scaling up on the control parameter of velocity. Thirty-six participants
(ages: 6-12 years) were categorized into four throwing levels according to
patterns represented by temporal joint lag. Each participant was required to complete 5 overhand throws at each of 10 relative velocities for a total of 50 trials per participant. The lowest velocity was 10% of maximum, with increases in increments of 10% up to a maximum effort. Quantitative and qualitative analyses indicated that critical values varied according to throwing category and joint.

Sherry, Werner, Thomas, Gill, Tricia, Murray, Timothy, Cook, Richard, & Hawkins, (2001) have studied on “Relationships between Throwing Mechanics and Shoulder Distraction in Professional Baseball Pitchers”. The extreme forces and torques and the high speeds and excessive ranges of motion of baseball pitching place tremendous stress on the soft tissues of the throwing shoulder. Little is known about the relationship between pitching mechanics and shoulder joint stress, especially in professional athletes. The purpose of this study was to quantify joint loads and kinematic parameters of pitching mechanics at the major league level and to study their relationships. Three-dimensional, high-speed video data were collected on 40 professional pitchers during the 1998 Cactus League spring training. A clinically significant distraction force was calculated at the shoulder joint, which reached an average peak value of 947 ± 162 N (108% ± 16% body weight). Descriptive statistics and a multiple linear regression analysis were used to relate shoulder distraction to kinematic
and kinetic parameters of pitching mechanics. This study was undertaken not only to investigate the peak forces and torques on the shoulder, but also to identify potential areas of intervention that might prevent throwing injuries. Knowledge of joint ranges of motion, angular velocities, and joint-reaction forces can provide a scientific basis for improved preventive and rehabilitative protocols for baseball pitchers.

Frank, Andrew, Rokito, & Frank, (2001) have studied on “Medial Elbow Problems in the Overhead-Throwing Athlete”. The elbow is subjected to enormous valgus stresses during the throwing motion, which places the overhead-throwing athlete at considerable risk for injury. Injuries involving the structures of the medial elbow occur in distinct patterns. Although acute injuries of the medial elbow can occur, the majority are overuse injuries as a result of the repetitive forces imparted to the elbow by throwing. Injury to the ulnar collateral ligament complex results in valgus instability. Valgus extension overload leads to diffuse osseous changes within the elbow joint and secondary postero medial impingement. Overuse of the flexor-pronator musculature may result in medial epicondylitis and occasional muscle tears and ruptures. Ulnar neuropathy is a common finding that maybe due to a variety of factors, including traction, friction, and compression of the ulnar nerve. Advances in nonoperative and operative treatment regimens specific to each injury
pattern have resulted in the restoration of elbow function and the successful return of most injured overhead athletes to competitive activities. With further insight into the relevant anatomy, biomechanics, and pathophysiology involved in overhead activities and their associated injuries, significant contributions can continue to be made toward prevention and treatment of these injuries.

John, Michael, Laura, Huston, Ralph, & Louis, (2000) have studied on “Ligamentous Restraints to External Rotation of the Humerus in the Late-Cocking Phase of Throwing”. The late-cocking phase of throwing is characterized by extreme external rotation of the abducted arm; repeated stress in this position is a potential source of glenohumeral joint laxity. To determine the ligamentous restraints for external rotation in this position, 20 cadaver shoulders (mean age, 65 ± 16 years) were dissected, leaving the rotator cuff tendons, coracoacromial ligament, glenohumeral capsule and ligaments, and coracohumeral ligament intact. The combined superior and middle glenohumeral ligaments, anterior band of the inferior glenohumeral ligament, and the entire inferior glenohumeral ligament were marked with sutures during arthroscopy. Specimens were mounted in a testing apparatus to simulate the late-cocking position. Forces of 22 N were applied to each of the rotator cuff tendons. An external rotation torque (0.06 N·m/sec to a peak of 3.4 N·m) was applied to the humerus of
each specimen with the capsule intact and again after a single randomly chosen ligament was cut ($N = 5$ in each group). Cutting the entire inferior glenohumeral ligament resulted in the greatest increase in external rotation ($10.2° \pm 4.9°$). This was not significantly different from sectioning the coracohumeral ligament ($8.6° \pm 7.3°$). The anterior band of the inferior glenohumeral ligament ($2.7° \pm 1.5°$) and the superior and middle glenohumeral ligaments ($0.7° \pm 0.3°$) were significantly less important in limiting external rotation.

Cook & Strike, (2000) have studied “Throwing in cricket”. This paper considers the kinematic characteristics of overarm throwing with particular emphasis on the techniques of throwing and pitching in baseball. The technique is subdivided into: (1) sequential pattern of throwing, (2) lead foot contact, (3) preparatory phase, (4) arm acceleration and (5) instant of ball release. Specific biomechanical principles that underpin throwing and their application within baseball are identified. The paper also presents a case study of the three-dimensional characteristics of throwing technique in cricket. The aim was to compare the skill in cricket to that previously researched in baseball. The findings for throwing in cricket are similar to those reported for baseball, indicating that there is a definite crossover in the rationale of how an individual should throw specific to the demands of cricket and baseball.
The differences noted - greater elbow flexion at lead foot contact and less external rotation during the preparation phase - can be attributed to the demands placed on the fielder and pitcher specific to their respective sports.

Chowdhary & Challis, (1999) have studied on “Timing Accuracy in Human Throwing”. This study examines the precision required in the timing of muscle activations and projectile release to hit a target of 20 cm in diameter oriented horizontally either 6 or 8 m away. Over-arm throws, constrained to the sagittal plane, were simulated using a muscle-actuated, two-segment model representing the forearm and hand plus projectile. The parameters defining the modeled muscles and the anthropometry were specific to two male subjects. An objective function specified that throws must be both fast and accurate. The launch window was the time available within which the projectile must be released and still strike the target. The window during which the wrist flexors could be activated was 10.41 ms (assuming the projectile was released at the pre-planned optimal time). Similar results were found for a second set of simulations. These simulations revealed the precise timings required in muscle activations and release required for fast accurate throws.

Fleisig, Barrentine, Zheng, Excamilla, & Andrews, (1999) have studied on “Biomechanical comparison of baseball pitching among various levels
of development”. To investigate the pitching motion at different levels of competition. 231 pitchers were subjects in the study: youth pitchers (n=23), high school pitchers (n=33), college pitchers (n=115), and professional pitchers (n=60). Their pitching motions were captured using four high-speed (200 Hz) infrared cameras and digitized. Angles, velocities, forces, and torques were then compared using the digitized data. There are no significant differences were found in the timing of various parts of the pitching motion among the different levels of development. Only one difference was found in the positions.

Escamilla, Fleisig, Barrentine, Zheng, & Andrews, (1998) have studied “kinematic comparisons of throwing different Types of baseball pitches”. The purpose of this study was to establish and compare kinematic data among four groups of collegiate pitchers who threw the fastball (FA), change-up (CH), curveball (CU), and slider (SL). Twenty-six kinematic parameters at lead foot contact, during the arm-cocking and arm acceleration phases, and at ball release were measured for 16 collegiate baseball pitchers. Approximately 60% of these parameters showed significant differences among the four pitch variations. The greatest number of differences (14 of 26) occurred between the FA and CH groups, while the fewest differences (2 of 26) occurred between the FA and SL groups. The CH group had the smallest knee and elbow flexion at
lead foot contact and the greatest knee and elbow flexion at ball release. During the arm-cocking and arm acceleration phases, peak shoulder, elbow, and trunk angular velocities were generally greatest in the FA and SL groups and smallest in the CH group. At ball release the CH group had the most upright trunk and the greatest horizontal shoulder adduction, while the CU group had the most lateral trunk tilt. Understanding kinematic differences can help a pitcher select and learn different pitches and can help a batter learn how to identify different pitches.

Hore, Watts, & Martin, (1996) have studied on “Finger flexion does not contribute to ball speed in over-arm throws”. The aim of this study was to determine whether, in over-arm throws made by recreational ball players, the fingers undergo flexion movement before ball release and thereby contribute to the generation of ball speed. To obtain the high resolution needed to answer this question, the magnetic-field search-coil technique was used and the data were sampled at 1000 Hz. The subjects, who were either seated or were standing, threw tennis balls at different speeds at a target. Angular positions in three dimensions were simultaneously recorded of the distal phalanx of the middle finger and hand and, in additional experiments to determine the mechanism of ball release in more detail, three middle finger phalanges and the hand. Different phases of ball release were determined by pressure-sensitive microswitches on
the proximal and distal phalanges of the middle finger. Irrespective of whether the subjects were seated or were standing, for all throws at all speeds, finger flexion did not occur before ball release. That is, up until final release of the ball, the fingers only underwent extension associated with hand opening. For fast throws, at the instant of final ball release the fingers began to flex, presumably as a result of reactive forces associated with release of the ball. Thus, in over-arm throws made by recreational ball players, finger flexion movement does not appear to contribute to the generation of ball speed.

Knudson & Morrison, (1996) have studied “The An Integrated Qualitative Analysis of Over-arm Throwing”. By applying an integrated model of qualitative analysis, teachers can give students specific, helpful cues that will lead to improved over-arm throwing performance. Qualitative analysis of motor skills must be based on information from many of the sub disciplines of physical education (biomechanics, exercise physiology, motor development, motor learning, pedagogy, sport psychology, etc.). These sources of information influence all four of the major tasks of qualitative analysis: preparation, observation, evaluation/diagnosis, and remediation. Professionals compile relevant information on the movement and on the performers to identify the critical features of the movement. Second, they systematically observe
the movement to gather information on the status of the performance. The third task of qualitative analysis the evaluation of the strengths and weakness of the performance, and the diagnosis of the most important correction. Fourth, the analyst provides one remedy or cue (feedback) based on the diagnosis that is likely to improve performance.

Neal, Snyder, & Kroonenberg, (1991) have studied on “Individual differences and segment interactions in throwing”. Arm segment velocities of 12 athletes throwing three differently weighted balks were analyzed by three-mode principal component analysis. Individual differences were characterized in terms of the combined influences of the phases of the throwing motion and the arm segment velocity relationships established in those phases. Using three individual differences components, three velocity measures components and four time phase components, 75% of the variance was described. The arm segment velocity relationships were described by two main components identified as directional velocity and proximal versus distal velocity. The time periods components distinguished between relationships among the segment velocities that occur in the windup versus those of the release phase. Three individual differences components are identified and appeared to be related to a general throwing style, the influence of skill level on technique, and the differential effect of the varying ball weights,
respectively. Each athlete's throws are weighted combinations of these three components. The timing of segment involvement is investigated and the results indicate sequential patterns from proximal to distal as the throw unfolds. However, the results also suggest that different principles may apply or different throwers and that the summation of speed principle should not be applied universally to explain segment motion and interaction.

Bingham, Geoffrey, Schmidt, Rosenblum, & Lawrence, (1989) have studied on “Hefting for a maximum distance throw”. Objects for throwing to a maximum distance were selected by hefting objects varying in size and weight. Preferred weights increased with size reproducing size-weight illusion scaling between weight and volume. In maximum distance throws, preferred objects were thrown the farthest. Throwing was related to hefting as a smart perceptual mechanism. Two strategies for conveying high kinetic energy to projectiles were investigated by studying the kinematics of hefting light, preferred, and heavy objects. Changes in tendon lengths occurring when objects of varying size were grasped corresponded to changes in stiffness at the wrist. Hefting with preferred objects produced an invariant phase between the wrist and elbow. This result corresponded to an optimal relation at peak kinetic
energy for the hefting. A paradigm for the study of perceptual properties was compared to size-weight illusion methodology.

Pappas, Richard, Zawacki, & Sullivan, (1985) have studied on “Biomechanics of baseball pitching”. Fifteen professional major league pitchers were filmed with high speed cinematography. One hundred forty-seven pitches were analyzed using an electromagnetic digitizer and a microcomputer. Three phases of throwing were studied: cocking, acceleration, and follow-through. The cocking phase is the period of time between the initiation of the windup and the moment at which the shoulder is in maximum external rotation. This phase occurs in approximately 1500 ms, and the shoulder is brought into an extreme position of external rotation. The acceleration phase and the initial stages of the follow-through phase produce extraordinary demands on the shoulder and elbow. The acceleration phase begins with the throwing shoulder in the position of maximum external rotation and terminates with ball release. This phase occurs in approximately 50 ms, and peak angular velocities averaging 6, 180 deg/sec for shoulder internal rotation and 4,595 deg/sec for elbow extension were measured. The follow-through phase begins at ball release and continues until the motion of throwing has ceased. This phase occurs in approximately 350 meters.
Barry, George, James, William, & Robert, (1980) have studied on “The throw: biomechanics and acute injury”. The throw and its modifications are integral components of many sports. This study correlates case histories of acute injuries in throwing with a biomechanical analysis of the throwing mechanism. Comparisons are made with a similar analysis of the kick analyzed by the same film technique and computer program. Just prior to ball release, the pitching arm extends through an arc of about 73 degrees in 40 m sec, beginning with the elbow flexed at 80 degrees. This produces an axial load on the humerus and coincides with a pulse of external torque at the shoulder. This acts as stress protection to the humerus which is developing internal torque of 14,000 inch-Ib prior to ball release. The change in angular velocity, or the angular acceleration, during the throw is acquired in a much shorter time than in the kick. Torque is directly proportional to angular acceleration. This necessitates the development of substantially higher torques in the humerus during the throw than about the knee during a kick. The kinetic energy in the arm is 27,000 inch-Ib during the throw. This is much higher than the kinetic energy in the kicking leg because the kinetic energy varies proportionally with the square of the angular velocity of the extremity. The angular velocity of the arm is about twice that of the leg. Thus, the pitching arm contains about four times as much kinetic energy as the kicking leg. This
severe overload throwing conditions predispose the upper extremity to injury in the throwing mechanism.